Aggregate Measures of Efficiency and Productivity Growth In the Korean Banking Industry, 1992-2002

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Abstract

In this paper we present estimates of Korean bank inefficiency and productivity change for the period 1992 to 2002 that are derived from the directional technology distance function. Our method controls for loan losses that are an undesirable by-product that arise from producing loans and allows the aggregation of individual bank inefficiency and productivity growth to the industry level. We find indicate that technical progress during the period was more than enough to offset efficiency declines so that the banking industry experienced productivity growth.

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1. Introduction

In this paper we investigate the effects of Korean financial liberalization and the Asian financial crisis on the efficiency and productivity growth of the Korean banking industry during the 1990s and early 2000s. Korea has played an important role in the financial sector of northeast Asia and as the Korean government recently implemented an ambitious plan to develop Korea as a financial hub for the region, it is worthwhile and timely to analyze the Korean banking industry's efficiency and productivity.

In measuring bank efficiency and productivity growth, we address certain empirical problems that have been encountered in bank efficiency studies. First, measures of technical efficiency estimated using Shephard (1974) output or input distance functions are not additive from the bank to the industry level. Thus, estimates of mean bank efficiency and its change over time provide minimal insight into industry performance. To address this problem, we use the directional technology distance function, which can be aggregated to an industry measure of performance. (Färe and Primont 2003, Färe and Grosskopf 2004) Second, the fact that some bank loans become non-performing and are eventually written off requires an efficiency measure that can account for both desirable outputs, such as bank loans and security investments, and undesirable by-products, such as non-performing loans. Again, the directional technology distance function is capable of modeling efficiency for firms that produce desirable outputs and undesirable outputs.

Given our panel data set consisting of between fourteen and twenty-six banks for the period 1992-2002, we also measure productivity growth and its decomposition into growth due to greater efficiency and growth due to technical change. These indicators of productivity growth can also be aggregated to the industry level. Many studies of firm productivity growth yield estimates of technical regress from period to period. The measured technical regress is usually thought to be an artifact of the method that defines the frontier. For example, when data envelopment analysis (DEA) is used to construct the production frontier, firms that exhibit the best-practice output-input combination define the frontier in a given period and are technically efficient. If those same firms produce less output or use more input in a subsequent period but still define the frontier, the inward shift of the frontier is denoted as technical regress, when it more logically could be deemed lower efficiency. In their examination of labor productivity growth across countries, Kumar and Russell (2002) measure technical regress for some countries that have low capital-labor ratios and write that the results:

> should be taken with a grain of salt. For one thing, it is not clear how the world frontier could implode at some capital-labor ratios. Does knowledge decay? Were "blueprints" lost? It is perhaps more likely that the “best-practice” frontier constructed by the DEA technique is well below the "true" but unobservable frontier at very low capital-labor ratios and therefore that the apparent technological degradation at these low levels of capitalization are in fact efficiency declines. (Kumar and Russell 2002, p. 540)

We address this problem in our model by specifying a current period technology that depends on current observations of inputs and outputs and the input-output combinations from all preceding periods using sequential reference sets (Tulkens and Eeckaut, 1995). Specifying the production technology in this manner means that our method will rule out technical regress as a source of productivity decline. Instead, should productivity declines occur, our method will assign those declines as arising from less efficiency. However, our method still does not measure efficiency relative to the true, but unobservable technology, but instead constructs the technology given the best-practice techniques of observed banks.

In the next section we provide a brief history of the Korean banking industry, including the various regulations faced by Korean banks and subsequent financial liberalization, the events that occurred prior to the Asian financial crisis, and subsequent post-crisis reforms. Section 3 reviews previous studies of Korean bank efficiency. In section 4 we present the method used to estimate efficiency and productivity growth. In section 5 we describe the data and estimates of Korean bank industry efficiency and productivity growth. In the final section we offer a summary of our work and draw conclusions.

2. The Korean Banking Industry: Regulation, Liberalization, Crisis, and Recovery

Since the 1960s, growth of the Korean banking sector coincides with rapid growth in the Korean economy. In fact, for the last twenty years Korean bank assets grew faster than the economy, with annual growth of 22%, compared to annual nominal GDP growth of 14%. During this period the Korean banking sector underwent many changes including nationalization, privatization, re-nationalization, re-privatization, financial liberalization, financial crisis, and, most recently, restructuring. Since these changes will likely impact the efficiency and productivity growth of Korean banks, we examine them here.

A few modern commercial banks were established in Korea during the Japanese occupation (1910-1945) and Korea inherited these banks when the Japanese colonial rule ended in 1945. After independence, the Korean government passed two important pieces of banking legislation in 1950: the Bank of Korea Act, which created the central bank, and the General Bank Act, which regulated privately held commercial banks. The General Bank Act of 1950 laid a foundation of sound banking guidelines. However, after the Korean War of 1950-1953, banks were nationalized as the government mobilized scarce financial resources for reconstruction and redevelopment of devastated industries. The establishment of a new regime by free election in 1960 resulted in a brief period of privatization and autonomy in management. However, a military coup in 1961 and the subsequent regime led by President Park reversed the course of privatization.

After the 1961 coup, five nationwide commercial banks were nationalized, which allowed the government to provide financing to targeted industries under a series of five-year plans. Import substitution industries were the first to be targeted, followed by export promotion industries, and then heavy and chemical industries. Several specialized banks were also established in the early 1960s to be operated outside of the central bank's authority and to finance government-targeted priority industries. Regional banks were introduced in the late 1960s to stimulate regional economic development. Within a few years, ten regional banks were established and remained in business until the Korean financial and currency crisis of 1997-1998. After the crisis, four regional banks were closed or merged with nationwide banks.

Commercial banks were the main instrument for carrying out government-initiated economic development plans during the 1960s and 1970s. The proportion of policy loans to domestic credit increased from 40% in the 1960s to 50% in the 1970s. It was during this period, particularly the 1970s, that Korean conglomerates or Chaebols were formed and given government protection. In order to promote heavy and chemical industries, proven entrepreneurs were asked to invest in targeted industries with government financial support in the form of subsidized loans at negative real interest rates, easy access to foreign exchanges, and tax concessions.

With inefficient banks facing financial difficulties and competition from an underground financial market, the Korean government introduced a series of reforms beginning with revisions to The General Banking Act in 1982. These revisions ushered in a period of gradual privatization and bank deregulation. Merchant banks and short-term finance firms were created to attract credit into the formal market. Moreover, nationwide commercial banks increased from five in 1980, to ten in 1990, to fourteen in 1993. While the intent of the regulatory reforms was to refocus government on the control of monetary aggregates, government continued to indirectly allocate credit through its influence on the appointment of top bank managers.

In response to pressure from the OECD and the US to open its financial markets, Korea began a series of revisions to the General Banking Act during 1991 to 1997. Interest rates were deregulated, policy loans and other credit controls were eliminated, reductions in non-performing loans were targeted, foreign exchange market transactions were deregulated, and bank ownership was restructured to allow individual shareholders up to a 12% equity stake.

The 1991 to 1997 reforms allowed Korean firms easier access to foreign capital without government approval and supervision, a fact that some observers attribute as a major cause of the Korean currency crisis of 1997-1998. Furthermore, a long period of recession and low domestic interest rates in Japan led to an influx of foreign capital to Asian countries. Contributing to the over-lending to Korean banks and firms was a moral hazard effect, as foreign lenders perceived explicit or implicit loan guarantees. A lack of appropriate supervision and regulation also allowed serious asset-liability mismatches to develop as long-term domestic loans were financed through short-term foreign borrowing, with short-term foreign debt accounting for up to 65% of total foreign debt.

Similar mismatches in the duration of loans and deposits caused the Savings and Loan Association Crisis of the 1980s in the US (Saunders, 2000).

The excessive borrowing by Korean banks financed investment in tradable goods by Chaebols, causing overcapacity in sectors such as automobiles and micro-chips, resulting in low profits and subsequent bad loans. According to Corsetti, Pesenti and Roubini (1999), evidence of risky overinvestment was seen in the high rate of non-performing loans and high leverage ratios of the corporate sector in the Asian countries that experienced the currency crisis. As non-performing loans increased, foreign creditors became less willing to refinance, igniting speculative attacks. In Korea, non-performing loans as a share of total loans reached 16% in June 1997 and then 22.5% in the first quarter of 1998 (Park, 2003).

The financial crisis of 1997-1998 brought about a significant transformation in the banking sector in Korea as the government carried out a two-stage financial restructuring. In the first stage, two banks were nationalized for later sale to foreigners, five insolvent banks were closed and then merged with blue-chip banks, inducements for foreign capital injections were given to seven banks, and public funds were used to normalize operations at the remaining surviving banks. Korean banks responded with cost reductions and the fastest disposal rate of non-performing loans among the Asian countries suffering the currency crisis.

The second stage of restructuring began in June 2000 and focused on restoring bank profitability. Financial holding companies were created to make merger and acquisition easier and help banks realize scale economies. Although bank concentration increased as nationwide banks gained market share in deposits and loans at the expense of regional banks, a study by the IMF (2001) found that Korean bank concentration was still low relative to OECD countries. The reforms also promoted market accounting methods, loan loss provisioning rules, and required equity capital injections into those banks affected by the recognition of loan losses. As a consequence of the equity capital injections, government ownership increased from less than 18% of total bank capital to over 56% of total bank capital. Foreign ownership of banks also increased to about 30% of Korean bank assets as foreign equity capital limits were eliminated.

Although Korean banks are more focused on profitability, the government is still indirectly engaged in credit allocation. Loan portfolios have shifted away from corporate loans toward household loans in response to government stimulants to domestic consumption to compensate for lower exports. Government stimulants include easing entry requirements into the credit card business, inducements to credit card companies to lower service fees for cash withdrawal, and to allow no-interest installment payments. Increased bank competition for household loans accompanied by easy financing resulted in high default rates of consumer and credit-card debts in 2003. Today, Korean bank profitability remains poor, due to a high share of nonperforming loans and inefficient pricing of credit risk. However, after four years of negative rates of return on assets and equity stemming from the crisis, both measures of profitability turned positive in 2001 and 2002.

3. Review of Previous Studies on Korean Bank Efficiency

Gilbert and Wilson (1998) investigate the effects of privatization and deregulation on the productivity of fourteen nationwide and ten regional Korean banks for the period 1980-1994. They find that Korean banks dramatically changed their mix of inputs and outputs as privatization and deregulation occurred during the 1980s and early 1990s. Using Malmquist indexes, they decompose productivity change into technical efficiency change and technological change and find that privatization and deregulation enhanced potential output as well as productivity among Korean banks.

Hao, Hunter, and Yang (2001) extend the analysis of Gilbert and Wilson (1998) to identify the key determinants of the efficiency gains. Using a stochastic cost frontier approach, they compute efficiency scores for a sample of nine nationwide banks and ten regional banks for the period 1985-1995. They find that banks with higher rates of asset growth, fewer employees per million won of assets, larger amounts of core deposits, lower expense ratios, and classification as a nationwide bank are more efficient. However, Hao, Hunter, and Yang find that the financial deregulation of 1991 had little or no significant effect on bank efficiency.

Extending the time frame of Gilbert and Wilson, Lee and Kwon (1999) find that financial liberalization in the 1990s helped enhance input technical efficiency of nationwide banks leading to a 2.7% annual productivity growth, while regional banks experienced declines in efficiency resulting in a 1% decline in productivity. Cho and Shin (2004) find that the five biggest Korean banks experienced a decline in rates of return during 1992-1997 relative to other Korean banks, although these big banks maintained greater cost and technical efficiency. Park and Kim (2002) estimated efficiency and productivity change for the period 1995-2000 and found that regional banks are less efficient and experience fewer gains in efficiency than nationwide banks. Park and Yi (2002) use data from the period 1995 to 1999 to estimate efficiency and simulate the effects of various hypothetical merger scenarios. They found evidence of decreasing returns to scale for mergers of two technically efficient banks, but if those same two banks produce different mixes of outputs, strong scope economies might arise via the merger.

4. Method - The Directional Output Distance Function

We use the directional technology distance function to model the production process of Korean banks. This directional distance function allows efficiency to be measured for firms that face a technology where both desirable outputs and undesirable outputs are produced. This function has been used in measuring the efficiency of firms or industries that generate polluting by-products in addition to desirable outputs. (Chung, Färe, and Grosskopf 1997, Färe et al. 2005, Yu 2004) For our purpose it is a useful tool for measuring the efficiency of banks that produce non-performing loans as a by-product of their loan portfolio. Similar models were also considered by Charnes et al. (1985) in a DEA setting. However, while the Charnes et al. additive DEA model yields an efficiency measure obtained by minimizing the slack in the output and input constraints, the directional distance function evaluates the inefficiency of a bank for a pre-specified direction to the frontier of the technology. Furthermore, the directional distance function can be estimated using nonparametric DEA methods as we do here, or using stochastic parametric methods.

Let $y \in R_+^M$ denote a vector of desirable outputs, $b \in R_+^J$ denote a vector of undesirable outputs, and $x \in R_+^N$ denote a vector of inputs. Production takes place in t=1,…,T periods by k=1,…,K banks. An observation on bank k in period t is represented by (x_k^t, y_k^t, b_k^t).

The technology, T, is the set of desirable outputs, undesirable outputs, and inputs such that the inputs can produce the outputs:

$$T = \{(x, y, b) : x \text{ can produce } (y, b)\}. \qquad (1)$$

We assume the technology is convex, compact, and satisfies the condition of no free lunch. We also assume the technology satisfies strong disposability (SD) of desirable outputs and inputs, weak disposability (WD) of desirable and undesirable outputs and inputs, and null-jointness (NJ). These properties are represented as:

$$\begin{array}{ll} SD & \text{If } (x,y,b)\in T \text{ and } (-x',y',b)\le(-x,y,b) \text{ then } (x',y',b)\in T \\ WD & \text{If } (x,y,b)\in T \text{ then } (\theta x,\theta y,\theta b)\in T \text{ for } 0\le\theta\le 1 \\ NJ & \text{If } (x,y,b)\in T \text{ and } b=0 \text{ then } y=0. \end{array} \tag{2}$$

Strong disposability implies that banks can use more input to produce the same amount of desirable and undesirable outputs, or, it can produce fewer desirable outputs and the same amount of undesirable outputs from a given level of inputs. However, SD is not a maintained assumption for the undesirable output, since there is an opportunity cost of disposing of undesirable outputs. Instead, we assume that desirable and undesirable outputs are weakly disposable. The assumption of weak disposability models the idea that there is a cost to reducing undesirable outputs. If banks want to reduce their non-performing loans, they must make fewer total loans. The property of no free lunch implies that if no input is available, no output can be produced.

We use data envelopment analysis (DEA) to represent the technology. The piece-wise linear constant returns to scale DEA technology for period j is usually written as

$$T^j=\{(x,y,b):\sum_{k=1}^{K} z_k^j x_k^j\le x,\sum_{k=1}^{K} z_k^j y_k^j\ge y,\sum_{k=1}^{K} z_k^j b_k^j=b,\, z_k^j\ge 0,\, k=1,\dots,K\}\ .$$

To address the concern of Kumar and Russell (2002) we modify the technology so that combinations of inputs that could produce the desirable and undesirable outputs in previous periods are feasible in the current period. The modified technology takes the form:

$$T^j = \{(x, y, b): \sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t x_k^t \le x, \sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t y_k^t \ge y, \sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t b_k^t = b,$$
$$z_k^t \ge 0, k = 1,..., K, t = 1,..., j\} \quad (3)$$

The best-practice technology is constructed from observations on all K banks in the current period, j, and each of the preceding periods, t<j, and is such that no less input can be used to produce no more desirable output and an equal amount of the undesirable output than a linear combination of observed inputs, desirable outputs, and undesirable outputs. The intensity variables, z_k^t, serve to form linear combinations of observations from the current and past periods. Constant returns to scale are imposed by constraining the intensity variables to be non-negative.

So that we might illustrate the technology in two-dimensional diagrams, we introduce three other sets that are equivalent representations of the technology. For ease of exposition we drop the time superscript temporarily. Holding undesirable outputs constant, the set $V(b)$ gives the set of feasible input-desirable output combinations:

$$V(b) = \{(x, y): (x, y, b) \in T\} . \quad (4)$$

The output possibility set $P(x)$, gives the set of desirable and undesirable outputs that can be produced from a given level of inputs:

$$P(x) = \{(y, b): (x, y, b) \in T\}. \quad (5)$$

Finally, the desirable output requirement set is the set of inputs and undesirable outputs that are feasible given desirable outputs:

$$L(y) = \{(x, b): (x, y, b) \in T\}. \quad (6)$$

The three technology sets are depicted in Figure 1. Each set is bounded. For the set $V(b)$, the horizontal extension to the east indicates that there is an upper bound on the amount of desirable output, y, that can be produced from input, x, given undesirable output b. For the output set $P(x)$, finite amounts of input can only yield finite amounts of desirable and undesirable outputs. For the set $L(y)$, there is a lower bound on the amount of undesirable output produced and input used given an amount of desirable output. We also note that the pseudo-isoquant for $V(y)$ can be backward bending because the undesirable output satisfies only weak disposability. Given the technology represented by the sets in Figure 1, suppose we observe a bank, represented by point A. Clearly bank A produces off the frontier of the technology set and is inefficient. That is, bank A should be able to use less input and produce more desirable output and less undesirable output given the technology. To measure inefficiency we use the directional technology distance function proposed by Chambers, Chung, and Färe (1996) as a generalization of the Luenberger (1992) benefit function. Let $g = (g_x, g_y, g_b)$ represent a directional vector. The directional technology distance function seeks the maximum simultaneous expansion of desirable outputs, contraction of undesirable outputs, and contraction of inputs for the directional vector, g. This function takes the form:

$$\vec{D}_T(x, y, b; g_x, g_y, g_b) = \max\{\beta : (x - \beta g_x, y + \beta g_y, b - \beta g_b) \in T\}. \quad (7)$$

Adding back the time superscript, the directional technology distance function for bank A in period j is estimated via DEA as:

$$\begin{aligned} \vec{D}_T^{\,j}(x, y, b; g_x, g_y, g_b) = \max\{\beta : \sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t x_k^t \le x_A^j - \beta g_x, \\ \sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t y_k^t \ge y_A^j + \beta g_y, \sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t b_k^t = b_A^j - \beta g_b, z_k^t \ge 0, k = 1,\ldots,K, t = 1,\ldots, j\}. \end{aligned} \quad (8)$$

Suppose we take the directional vector to be $g = (g_x, g_y, g_b) = (1,1,1)$. For this directional vector, the solution to (8) gives the maximum unit expansion in desirable output and simultaneous unit contraction in undesirable outputs and inputs that is feasible given the technology. Other directional vectors can also be chosen. A directional vector such as g=(x,0,0) would give the percentage contraction in inputs, holding outputs fixed. A direction such as g=(0,y,b) would give the percentage expansion in desirable output and contraction in undesirable output, given inputs.

In Figure 1 we illustrate the movement of an observation such as bank A, with coordinates (x_A, y_A, b_A), toward the frontier of each set given the value of the directional distance function, β*. The frontier coordinates of bank A are $(x_A - \beta^* g_x, y + \beta^* g_y, b - \beta^* g_b)$. Banks that produce on the frontier are efficient and with $\vec{D}_T(x, y, b; g_x, g_y, g_b) = 0$. Values of $\vec{D}_T(x, y, b; g_x, g_y, g_b) > 0$ indicate inefficiency for the g-directional vector.

The directional technology distance function is a generalization of Shephard output or input distance functions. Shephard's input distance function is defined as

$$D_i(y, b, x) = \max\{\lambda : \frac{x}{\lambda} \in L(y)\}. \tag{9}$$

The Shephard input distance function seeks the maximum proportional contraction of inputs that can still produce the output vector (y,b) and can be derived from the directional distance function by setting $g = (x, 0, 0)$. That is,

$$\vec{D}_T(x, y, b; x, 0, 0) = 1 - \frac{1}{D_i(y, b, x)}. \tag{10}$$

Shephard's output distance function is defined as

$$D_o(x, y, b) = \min\{\delta : \frac{(y, b)}{\delta} \in P(x). \tag{11}$$

The reciprocal of the output distance function yields the proportional expansion in desirable outputs and undesirable outputs that is feasible given inputs. The output distance function can be obtained from the directional distance function by setting $g = (0, y, -b)$:

$$\vec{D}_T(x, y, b; 0, y, -b) = \frac{1}{D_o(x, y, b)} - 1. \tag{12}$$

We note that we take a negative direction for the undesirable output since our definition in (7) subtracts βg_b in computing the directional distance function. While the Shephard output distance function can be used to measure bank efficiency, bank managers are generally not interested in maximizing desirable and undesirable outputs simultaneously. Instead, bank managers seek to expand desirable outputs and contract undesirable outputs, such as non-performing loans, providing the rationale for our use of the directional distance function.

When all banks are evaluated for a common direction, Färe and Grosskopf (2004) show that an industry measure of inefficiency can be obtained as the sum the directional distance functions for the firms in the industry. Although Shephard output or input distance functions can be derived from the directional distance function, these Shephard distance functions use firm specific directional vectors and cannot be aggregated to the industry level. Devaney and Weber (2002) estimate US bank efficiency using the directional distance function, but do not account for non-performing loans and their choice of directional vector does not allow for consistent aggregation to an industry efficiency measure. Fukuyama and Weber (2004) provide an example of the aggregation property of directional distance functions for Japanese banks, but do not account for non-performing loans.

To measure productivity growth, the directional distance function must be evaluated in different periods. Caves, Christensen, and Diewert (1982) develop a

Malmquist index, equal to the ratio of two Shephard distance functions, to measure total factor productivity growth. Extending the work of Caves et al. by accounting for undesirable outputs Chung, Färe, and Grosskopf (1997) and Weber and Domazlicky (2001) define a productivity change index equal to the geometric mean of two Malmquist indexes and decompose productivity change into the product of an index of efficiency change and an index of technical change. Given the additive nature of the Luenberger directional technology distance function, productivity change is more naturally decomposed into additive indicators of efficiency change and technical change. Färe and Grosskopf (2004) derive additive Luenberger productivity indicators. They use the term "indicator" to denote the difference in two efficiency measures, rather than "index," which commonly refers to the ratio of two efficiency measures. We follow Färe and Grosskopf and evaluate the directional distance function in period j and period j+1 to measure efficiency change. We also estimate how far an observation (x^j, y^j, b^j) is from the period j+1 frontier, and how far an observation $(x^{j+1}, y^{j+1}, b^{j+1})$ is from the period j frontier, so that we can estimate technical change. The efficiency change component measures "catching up" to the frontier and the technical change component measures the shift in the frontier from period to period. The two inter-period directional distance functions are estimated as:

$$\begin{aligned}&\vec{D}_T^{\,j+1}(x^j, y^j, b^j; g_x, g_y, g_b) = \max\{\beta : \sum_{t=1}^{j+1}\sum_{k=1}^{K} z_k^t x_k^t \le x_A^j - \beta g_x,\\ &\sum_{t=1}^{j+1}\sum_{k=1}^{K} z_k^t y_k^t \ge y_A^j + \beta g_y, \sum_{t=1}^{j+1}\sum_{k=1}^{K} z_k^t b_k^t = b_A^j - \beta g_b, z_k^t \ge 0, k = 1,..., K, t = 1,..., j+1\}\end{aligned} \tag{13}$$

and

$$\vec{D}_T^{\,j}(x^{j+1}, y^{j+1}, b^{j+1}; g_x, g_y, g_b) = \max\{\beta : \sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t x_k^t \le x_A^{j+1} - \beta g_x,$$
$$\sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t y_k^t \ge y_A^{j+1} + \beta g_y, \sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t b_k^t = b_A^{j+1} - \beta g_b, z_k^t \ge 0, k = 1,..., K, t = 1,..., j\}. \quad (14)$$

Problem (13) estimates how far the period t observations on inputs and outputs are from the period *j*+1 technological frontier. Problem (14) estimates how far the period *j*+1 observations on inputs and outputs are from the period t technological frontier.

The Luenberger productivity indicator is

$$L(x^j, y^j, b^j, x^{j+1}, y^{j+1}, b^{j+1}; g_x, g_y, g_b) = \frac{1}{2}\{\vec{D}_T^{\,j+1}(x^j, y^j, b^j; g_x, g_y, g_b) - \vec{D}_T^{\,j+1}(x^{j+1}, y^{j+1}, b^{j+1}; g_x, g_y, g_b)$$
$$+ \vec{D}_T^{\,j}(x^j, y^j, b^j; g_x, g_y, g_b) - \vec{D}_T^{\,j}(x^{j+1}, y^{j+1}, b^{j+1}; g_x, g_y, g_b)\}. \quad (15)$$

The Luenberger productivity indicator can be decomposed into the sum of an indicator of efficiency change, EFFCH, and an indicator of technical change, TECH. These indicators take the form

$$EFFCH = \vec{D}_T^{\,j}(x^j, y^j, b^j; g_x, g_y, g_b) - \vec{D}_T^{\,j+1}(x^{j+1}, y^{j+1}, b^{j+1}; g_x, g_y, g_b) \text{ and} \quad (16)$$

$$TECH = \frac{1}{2}\{\vec{D}_T^{\,j+1}(x^j, y^j, b^j; g_x, g_y, g_b) + \vec{D}_T^{\,j+1}(x^{j+1}, y^{j+1}, b^{j+1}; g_x, g_y, g_b)$$
$$- \vec{D}_T^{\,j}(x^j, y^j, b^j; g_x, g_y, g_b) - \vec{D}_T^{\,j}(x^{j+1}, y^{j+1}, b^{j+1}; g_x, g_y, g_b)\} \quad (17)$$

where $L(x^j, y^j, b^j, x^{j+1}, y^{j+1}, b^{j+1}; g_x, g_y, g_b) = EFFCH + TECH$. Values of the indicators greater than zero indicate productivity growth, greater efficiency, or technical progress. Values of the indicators less than zero indicate a decline in productivity, less efficiency, or technical regress.

5. Data and Empirical Estimates

The data we use to estimate efficiency and productivity change are from the financial statements of Korean banks during the period 1992-2002, compiled by the

Korea Financial Supervisory Service, and the *Bank Management Statistics* of the Bank of Korea. The names of the nationwide and regional banks are included in Appendix A. We confine our analysis to banks that report positive equity capital and positive amounts of non-performing loans in a year. A loan is defined as non-performing if no payment has been received by the bank in the past ninety days or if the borrower has declared bankruptcy. While several new banks opened in the latter part of the period, they report zero amounts of non-performing loans in their first year of operation. In subsequent periods the non-performing loans of these banks are positive, and we include them in our analysis. The Korean banking industry consists of twenty-four banks in 1992-1994 and grows to twenty-five in 1995 and 1996, and to twenty-six in 1997. The financial crisis of 1997-1998 brought about a significant transformation of the Korean banking industry which we describe in section 2. In 1998 two new banks join twenty surviving banks, but by 1999 and 2000 only seventeen banks remain in operation, declining to fifteen in 2001 and fourteen in 2002.

Berger and Humphrey (1992, 1997) provide a review of financial institution efficiency studies and the various methods used to define inputs and outputs in financial services. The asset approach defines loans and other assets as outputs, while deposits, other liabilities, labor and physical capital are treated as inputs. The value-added approach defines outputs as those assets and liabilities that add substantial value to the bank and includes labor and the value of premises and fixed assets (physical capital) as inputs. The user-cost approach of Hancock (1985) defines outputs as those assets or liabilities that contribute to a bank's revenues and defines inputs as labor and those assets or liabilities that contribute to a bank's cost of production. Tortosa-Ausina (2002) finds significant differences in measured bank efficiency for the asset approach and a variant of the value-added approach.

Banks also engage in various off-balance sheet activities such as buying and selling interest rate options or foreign exchange options and making loan commitments that generate fee income and contingent obligations. Berger and Mester (1997) include the credit equivalent amount of off-balance sheet activity as a fixed netput that impacts bank profitability. Rogers (1998) includes fee income as a non-priced output to proxy off-balance sheet activity in his model of US commercial bank profit efficiency. He finds that models ignoring off-balance sheet activity understate bank efficiency.

Banks also operate in a regulatory environment which requires them to maintain minimum amounts of equity capital. In deciding the appropriate output-input mix, bank managers must account for the risk-return preferences of bank owners. Some bank managers might choose to employ larger amounts of labor to monitor risky loans and investments to preserve equity capital. Other bank managers might use less labor, resulting in lower costs, but greater risk. Färe, Grosskopf, and Weber (2004) test for the effects of bank regulatory requirements and the risk-return tradeoff on bank profit efficiency and find that using bank equity capital as a quasi-fixed input is sufficient to account for both risk-based capital requirements and the risk-return tradeoff that bank owners face. We follow the work of Färe, Grosskopf, and Weber (2004) and add an equity capital constraint to our DEA estimate of the directional distance function in (8) and the mixed period problems given in (13) and (14). This equity capital (*eq*) constraint is $\sum_{t=1}^{j}\sum_{k=1}^{K} z_k^t eq_k^t \le eq_A^j$.

Given the sensitivity of efficiency estimates to output and input specification we estimate five alternative models. In Model 1, we assume that Korean banks produce three desirable outputs and one undesirable output, using three variable inputs and one fixed input. The desirable outputs are commercial loans (y_1), personal loans (y_2), and securities (y_3). The undesirable output (b_1) is non-performing loans. The three variable inputs are full-time labor (x_1), physical capital which is measured as the asset value of premises and fixed assets (x_2), and total deposits (x_3). In Model 2 we follow Rogers (1998) and include fee income (y_9) as an additional output. In Model 3 we follow Tortosa-Ausina (2002) and include demand deposits (y_4) along with the outputs from Model 2. The output specification for Model 3 is also similar to that of Hao et al. (2001) in their estimation of a cost function for Korean banks.

Models 1, 2, and 3 the same inputs (x_1, x_2, x_3) are used to produce non-performing loans and various desirable outputs. The DEA technology defined by (3) depends on the number of input and output constraints. A consequence of increasing the number of desirable outputs as we move from Model 1 to Model 3 is that the technology, T, becomes more constrained and thus, measured inefficiency will not increase.

Two other output-input specifications are also considered. The previously noted argument of Park and Yi (2002) suggests that deposits are not an appropriate input. For this reason and for further comparison we consider two other output-input specifications. In Model 4, we follow the work of Hunter and Timme (1986) and define outputs as securities investments (y_3), total loans less non-performing loans ($y_5=y_1+y_2-b_1$), total deposits (y_6) and fee income (y_9). Model 4 inputs include labor (x_1) and physical capital (x_2). In Model 5 we follow the work of Sturm and Williams (2004) and assume that interest income (y_7) and non-interest income (y_8) are produced from interest expense (x_4)

and non-interest expense (x_5). After the crisis, the number of part-time and contractual workers increased relative to full-time labor as banks tried to reduce costs. In 1992, less than 3% of total workers were part-time. This average increased to 5% in 1995, 11% in 1996 and 1997, and to over 20% during 1999-2000. Unfortunately, our data do not provide the number of hours worked for these part-time and contractual workers. However, the expenses for these workers are included in non-interest expenses in Model 5 and will provide a comparison with the estimates of Models 1-4.

Descriptive statistics on each of the outputs and inputs for our pooled sample of 229 banks are provided in Table 1. We deflate the desirable outputs, non-performing loans, value of physical capital, deposits, financial equity capital, interest income, non-interest income, interest expense, and non-interest expense by the Korean GDP deflator in each year. Labor is measured as the number of full-time employed workers, and the other inputs and all outputs are in 100 million Korean won. As a percent of total bank assets, commercial loans (y_1) average 33.5% in the years 1992-96 before the financial crisis, but only 27% of total assets in the years 1999-2000 following the crisis. Personal loans (y_2) and securities (y_3) grow from an average of 5% and 16% of total assets in the years before the crisis, to 14% and 26% in the years following the crisis. Non-performing loans (b_1) average 3.6% of assets in the years before the crisis, grow to 6.4% of total assets in the crisis years of 1997 and 1998, and then fall to 3.6% of assets in the years following the crisis. Financial equity capital as a percent of assets is 10% in the pre-crisis years, 4.5% of assets in the two-year crisis period, and 4.9% of assets in the post-crisis years. Net income equals the difference between the output and inputs of Model 4 (y_7+y_8-x_3-x_4), is positive, but decreasing during 1992-1996, is negative during 1997-2000 reaching a low in 1998, and then is positive in 2001-2002. As a percent of equity capital, net income averages between 4% and 7% during 1992-1996 and is about 12% percent during 2001-2002. During 1997-2000 banks incur a negative return on equity which reaches five times the level of equity capital in 1998. Fees (y_9) average 6% of the sum of interest income and non-interest income. Banks employ an average of 4094 full-time workers, use physical capital equal to 6457 x100 million Korean won, and use 119,851 x 100 million won in deposits to produce the outputs.

To estimate the directional technology distance function and productivity change, a directional vector must be chosen. We consider three alternative directional vectors. In the first case, we choose a directional vector that equals to the mean output-input values as reported in Table 1. That is, we take $g = (\bar{x}, \bar{y}, \bar{b})$. For instance, in Model 1, with three inputs, three desirable outputs, and nonperforming loans, $g = (\bar{x}_1, \bar{x}_2, \bar{x}_3, \bar{y}_1, \bar{y}_2, \bar{y}_3, \bar{b}_1)$=(4094, 6457, 119851, 43472, 18882, 34939, 7049). In the second case, we choose a directional vector equal to $g = (0, \bar{y}, \bar{b})$. For this second case we hold input constant and estimate the maximum simultaneous expansion in desirable output and contraction in undesirable output. For our third case, we choose a directional vector equal to $g = (\bar{x}, 0, 0)$. Here, we hold desirable and undesirable outputs constant and estimate the maximum contraction inputs.

To interpret the results, consider the estimates for the directional vector $g = (\bar{x}, \bar{y}, \bar{b})$. For this directional vector, suppose that a bank has measured inefficiency of $\vec{D}_T(x, y, b; g_x, g_y, g_b) = 0.02$. The directional distance function gives the expansion in desirable outputs, contraction in undesirable outputs, and simultaneous contraction in inputs multiplied by the directional vector. Thus, if this hypothetical bank were to operate efficiently on the frontier of the T, it could expand commercial loans by 0.02 x 43472=869, expand personal loans by 0.02 x 18882=378, expand securities by 0.02 x =34939=699, contract non-performing loans by 0.02 x 7049=141, while using 0.02 x 4094=82 fewer workers, 0.02 x 6457=129 less in physical capital, and 0.02 x 119851= 2397 fewer deposits.

Banks with an estimate of $\vec{D}_T(x, y, b; g_x, g_y, g_b) = 0$ are efficient and produce on the frontier. Table 2 reports the number of banks that define the frontier in each year for each model and divides the number of frontier banks into national banks and regional banks. National banks are large, have offices throughout the country, and tend to have more diversified loan portfolios than regional banks. For Models 1, 2, and 3 the number of frontier banks declines from 1992 until 1998. A higher percentage of regional banks are on the frontier during 1992-1995, but by 1996 and especially in 1998, a lower percentage of regional banks are on the frontier. During 1999-2001 the number of frontier banks increase, but then fall in 2002. For Models 4 and 5 a smaller number of banks define the frontier. For Model 4, a higher percent of percent of nationwide banks are on the frontier while for Model 5, a higher percent of regional banks produce on the frontier in the early part of the period and in 2002. The difference in the number of frontier banks for Model 4 versus Models 1, 2, and 3 is partially explained by the treatment of total deposits, which are an input in the first three models and an output in Model 4. Banks that are successful in minimizing the input of deposits will appear to be inefficient when deposits are taken as an output.

When the directional technology distance function for each bank is estimated for a common directional vector, the sum of the directional distance functions is a measure of industry performance. (Färe and Primont 2003, Färe and Grosskopf 2004) In Table 3A, 3B, and 3C we report the annual estimates of industry inefficiency and Figure 2 depicts this performance graphically for the directional vector $g = (\bar{x}, \bar{y}, \bar{b})$. Industry inefficiency before the Asian financial crisis increases, more than doubling from 1992 to 1995 (except for Model 4), and then doubling again from 1995 to 1998 (except for Model 5). This increase in inefficiency might be partly explained by the fact that during the financial liberalization period before the crisis, the Korean government maintained an anti-merger policy. As a consequence, inefficient banks that might have been acquired remained in business, diluting the market share of efficient banks. After the crisis, industry inefficiency declines during 1998 to 1999 and declines even further in Models 3 and 5 during 2000. This decline in industry inefficiency is explained in part by the Korean government abandoning its anti-merger policy, which brought about an exodus of inefficient banks by closure and through mergers and acquisitions. From 2000-2002, industry inefficiency rises for Models 1, 2, and 3, remains constant for Model 4, and declines for Model 5. As expected, industry inefficiency for Model 3 is less than that estimated for Models 1 and 2 given the larger number of outputs in Model 3 relative to Models 1 and 2.

Tables 4A, 4B, and 4C present the estimates of the components of industry productivity growth (L) and its decomposition into the sum of an efficiency change indicator (EFFCH) and a technical change indicator (TECH). To interpret the results, we examine industry productivity growth during 1992-93 for Model 1, where productivity growth (L = 0.466) equals the sum of efficiency change (EFFCH = -0.047) and technical change (TECH = 0.513). Efficiency change is negative, indicating a decline in efficiency from 1992 to 1993. Multiplying EFFCH by the directional vector *g*, gives the change in outputs and inputs for the period 1992 to 1993. That is,

$dy = EFFCHx(g_{y_1}, g_{y_2}, g_{y_3})$, $db = EFFCHx(g_b)$, and $dx = EFFCHx(g_{x_1}, g_{x_2}, g_{x_3})$. For the directional vector $g = (\bar{x}, \bar{y}, \bar{b})$ the decline in efficiency means the industry produces $dy = 0.047x(43472, 18882, 34939) = (2043, 887, 1642)$ fewer desirable outputs (commercial loans, personal loans, securities) and $db = 0.047\ x\ 7049 = 331$ more non-performing loans, using $dx = 0.047x(4094, 6457, 119851) = (192, 303, 5633)$ more inputs (labor, capital, deposits) than in 1992. However, technical change is TECH=0.514, so the decline in efficiency is more than offset by gains in outputs and declines in non-performing loans and input usage brought about by technical progress. Therefore, by 1993, more commercial loans, more personal loans, more securities, and fewer non-performing loans are produced from fewer inputs than in 1992.

In Figures 3, 4, and 5 we graph the components of industry productivity change. First, we note that by construction, our indicator of technical change is positive in each period. Second, although industry efficiency frequently declines from period to period, those declines are offset by positive technical change. In fact, the magnitude of the technical change indicator is such that with the exception of Model 5 during 1992-1995, Model 2 in 1999-2000, and Model 4 in 2000-2001, the Korean banking industry experienced productivity growth in every year, including the years of the Asian financial crisis.

Given the importance of technical progress in driving productivity growth, how can we be sure that technical progress actually occurred? In 1992 the Korean banking industry consisted of 24 banks. If those 24 banks from 1992 were able to face the 2002 production technology, how inefficient would they be relative to their inefficiency in

1992? In Table 5 we present the number of banks in years prior to 2002 that would be deemed efficient for the 2002 technology. For instance, for Model 1, 2, and 3 the 1992 observations of outputs and inputs for eight, thirteen, and twenty-one banks would have been efficient relative to the 2002 technology. For Models 4 and 5, the same analysis is true for only one and six banks. It appears as if little technical change has occurred during the period. However, only twelve banks from 1992 survived to 2002. Moreover, the mix of outputs changed significantly from 1992 to 2002 with banks producing fewer commercial loans, more securities, and more personal loans in 2002 than in 1992. Beginning in 1993 and continuing to 1996, there is a sharp fall in the number of banks from previous periods that are still efficient in 2002. After 1996, as the years progress and become closer to 2002, the number of banks that are efficient relative to the 2002 technology tends to increase. We also re-estimated each of the five models using the standard DEA method by assuming a technology in the current year that does not depend on prior years. We find that in some years, notably 1997-98 and 1998-99, more than half of all the banks experienced technical regress. Since the "blue-prints" were not likely lost but maybe only misplaced for a short while given the Asian financial crisis, we think that our newer method of incorporating prior year's data in constructing the current year's technology provides a better measure of technical progress from year to year.

To further examine the issue of technical progress, we examine the distributions of inefficiencies of the 1992 observations of bank outputs and inputs relative to the 1992 technology and relative to the 2002 technology. Since our method is nonparametric, standard *t*-tests are not valid. Instead, we use the T-test proposed by Li (1996) to evaluate the difference in two kernel distributions of inefficiency. We estimate a standard normal kernel distribution following Pagan and Ullah (1999). Let

$f(\vec{D}_T^{1992}(x^{1992}, y^{1992}, b^{1992}; g_x, g_y, g_b)$ represent the kernel distribution of 1992 inefficiencies and let $g(\vec{D}_T^{2002}(x^{1992}, y^{1992}, b^{1992}; g_x, g_y, g_b)$ represent the distribution of inefficiencies for the 1992 observations relative to the 2002 frontier technology. We wish to test whether $f(.) = g(.)$. No technical progress occurs if we find that the two distribution functions of inefficiencies are equal. On the other hand, if the distribution of inefficiencies for 1992 lies to the left of the distribution of inefficiencies if the banks faced the 2002 technology, then it is a greater distance from the 1992 observations to the 2002 frontier than it is from the 1992 observations to the 1992 frontier. This finding would indicate technical progress. For each model, we provide Li's statistic for differences in the two distributions in Table 5 (critical T=1.71 for α=.05 and a one-tail test). The test results indicate technical progress during the period for Models 1, 2, and 5. By the year 2002, only fourteen banks remained in the Korean banking industry. We perform a similar kernel distribution test for these banks to test the hypothesis whether or not $f(\vec{D}_T^{1992}(x^{2002}, y^{2002}, b^{2002}; g_x, g_y, g_b) = g(\vec{D}_T^{2002}(x^{2002}, y^{2002}, b^{2002}; g_x, g_y, g_b)$. If technical progress occurs, then we would expect the 2002 observations to lie outside the 1992 frontier with $\vec{D}_T^{1992}(x^{2002}, y^{2002}, b^{2002}; g_x, g_y, g_b) < 0$ for the fourteen banks. Except for Model 3, our tests reject the null hypothesis of no technical progress.

Our productivity estimates indicate that technical progress was strong enough during the period to offset declines in efficiency. That is, the frontiers of the sets $V(b)$ and $P(x)$ have been pushed to the northwest, and the frontier of the set $L(y)$ has been pushed to the southwest in Figure 1. Our results indicate that the bank reforms of the 1990s and early 2000s were successful in generating productivity growth. While all the banks experience technical progress during the period, most banks fail to keep up with the pacesetting banks, resulting in greater inefficiency. Our results are also consistent with accounting measures of profitability, such as return on equity (ROE) and return on assets (ROA). The ROE of Korean banks is 6.7% in 1992 and declines to 3.8% in 1996. By 1997, ROE is negative and reaches a low of -53% in 1998. During 1999 and 2000 ROE remains negative, but losses narrow. By 2001 and 2002 ROE recovers to 16% and 11.7%. A similar pattern is seen with ROA.

6. Conclusions

In 1997-1998 the Asian economies experienced a financial crisis and contagion brought on by lax regulatory oversight, government-subsidized lending, moral hazard, and global financial integration. In Korea, the financial crisis was preceded by government deregulation and privatization of banks and in its wake, by re-regulation, restructuring, government and foreign equity capital injections, and a refocusing on bank efficiency and profitability.

In this paper we examine the efficiency and productivity growth of Korean banks during the period 1992-2002. We measure efficiency and productivity change using the directional technology distance function. This distance function allows us to aggregate individual bank efficiency and productivity indicators to the industry level and control for non-performing loans, which are an undesirable by-product of the loan production process. Furthermore, in measuring productivity change, we propose a technology that depends on past period outcomes as well as current period outcomes. As a consequence of our method, declines in productivity are assigned as declines in efficiency, rather than technological regress. We find that in the years before the Asian financial crisis, inefficiency in the Korean banking industry increased dramatically. Although the banking industry became less efficient throughout the period, technical progress more than offset declines in efficiency. During 1992-2002 the banking industry experienced productivity growth, brought about primarily by technical progress.

Appendix: List of Korean Commercial Banks

Nationwide Banks

1. Cho Hung Bank
2. Commercial Bank of Korea (merged to form Hanvit Bank in 1999)
3. Korea First Bank (nationalized in 1998)
4. Hanil Bank (merged to form Hanvit Bank in 1999)
5. Bank of Seoul (nationalized in 1998)
6. Korea Exchange Bank
7. Shinhan Bank
8. Hanmi Bank (KorAm Bank)
9. Dongwha Bank (acquired by Shinhan in 1998)
10. Dongnam Bank (acquired by Housing and Commercial Bank in 1998)
11. Daedong Bank (acquired by Kookmin Bank in 1998)
12. Hana Bank
13. Boram Bank (merged into Hana bank in 1999)
14. Peace Bank (merged into Woori Holding Co. in 2001)
15. Kookmin Bank (converted from a special bank in 1995)
16. Housing and Commercial Bank (converted from a special bank in 1997 and merged into Kookmin Bank in 2001)
17. Woori Holding Co. (former Hanvit Bank renamed in 2002 when it became a financial holding company)

Regional Banks

1. Daegu Bank
2. Pusan Bank
3. Chung Chong Bank (acquired by Hana Bank in 1998)
4. Kwangju Bank
5. Bank of Cheju
6. Kyungki Bank (acquired by Hanmi Bnk in 1998)
7. Jeonbuk Bank
8. Kangwon Bank (merged into Cho Hung Bank in 1999)
9. Kyungnam Bank
10. Choongbuk Bank (merged into Cho Hung Bank in 1999)

References

Bank of Korea, various years. *Bank Management Statistics* (in Korean).

Berger, A. and Humphrey, D., 1992. Measurement and efficiency issues in commercial banking, In Zvi Griliches, ed., *Output Measurement in the Service Industry*. Chicago: University of Chicago Press, National Bureau of Economic Research, 245-296.

Berger, A. and Humphrey, D., 1997. Efficiency of financial institutions: international survey and directions for future research, *European Journal of Operational Research* 98, 175-212.

Berger, A. and Mester, L. 1997. Inside the black box: what explains differences in the efficiencies of financial institutions? Journal of Banking and Finance, 21, 895-947.

Caves, D., Christensen, L., and Diewert, E., 1982. The economic theory of index numbers and the measurement of input, ouput, and productivity. *Econometrica* 50, 1393-1414.

Chambers, R., Chung, Y., and Färe, R., 1996. Benefit and distance functions. *Journal of Economic Theory* 70, 407-419.

Charnes, A., Cooper, W. W., Golany, B., Seiford, L.M., Stutz, J. 1985. Foundations of data envelopment analysis for Pareto-Koopmans efficient empirical production functions. *Journal of Econometrics*, 30, 91-107.

Cho, B.T. and Shin, D.J. 2004. A data envelopment analysis of efficiency in the five big banks before and after the 1997 banking crisis in Korea (in Korean). Joint Economics Conference-Korea Monetary Finance Association.

Chung, Y., Färe, R., and Grosskopf, S., 1997. Productivity and undesirable outputs: a directional distance function approach. *Journal of Environmental Management*, 51, 229-240.

Corsetti, G., Pesenti, P. and Roubini, N., 1999. What caused the Asian currency and financial crisis? *Japan and the World Economy*, Vol. 11 (1999): 305-373.

Devaney, M. and Weber, W., 2002. Small-business lending and profit efficiency in commercial banking. *Journal of Financial Services Research* 22, 225-246.

Färe, R. and Grosskopf, S., 2004. *New Directions: Efficiency and Productivity*, Kluwer Academic Publishers, Boston/London/Dordrecht.

Färe, R., Grosskopf, S., Noh, D.W., and Weber, W. 2005. Characteristics of a polluting technology, forthcoming in *Journal of Econometrics*.

Färe, R., Grosskopf, S., and Weber, W. 2004. The effect of risk-based capital requirements on profit efficiency in banking. *Applied Economics* 36, 1731-1743.

Färe, Rolf and Primont, D., 2003. Luenberger productivity indicators: aggregation across firms. *Journal of Productivity Analysis* 20, 425-435.

Fukuyama, H. and Weber, W., 2004. Efficiency and profitability in the Japanese banking industry. In: Färe and Grosskopf, *New Directions: Efficiency and Productivity* Kluwer Academic Publishers.

Gilbert, R. and Wilson, P., 1998. Effects of deregulation on the productivity of Korean banks. *Journal of Economics and Business* 50, 133-155.

Hao, J., Hunter, W., and Yang, W., 2001. Deregulation and efficiency: the case of private Korean banks. *Journal of Economics and Business* 53, 237-254.

Hancock, D., 1985. The financial firm: production with monetary and non-monetary goods. *Journal of Political Economy* 93, 859-880.

Hunter, W.C. and Timme, S. G. 1986. Technical change, organizational form, and the structure of bank production. *Journal of Money, Credit, and Banking* 18, 152-166.

International Monetary Fund, 2001. *Republic of Korea: Selected Issues*, Washington,D.C.

Korea Financial Supervisory Service. various years. *Financial statements of Korean commercial banks* (in Korean).

Kumar, S. and Russell, R., 2002. Technological change, technological catch-up and capital deepening: relative contributions to growth and convergence. *The American Economic Review* 92, 527-548.

Lee, S. K. and Kwon, Y.J. 1999. The sources of productivity change in Korean banking industry: application of a Malmquist approach. (in Korean) *Journal of Korea Monetary Finance*, 4.

Li, Q., 1996. Nonparametric testing of closeness between two unknown distribution functions. *Econometric Reviews* 15, 261-274.

Luenberger, D., 1992. Benefit functions and duality. *Journal of Mathematical Economics* 21, 461-481.

Pagan, A. and Ullah, A., 1999. *Nonparametric Econometrics* Cambridge University Press: Cambridge: UK.

Park, K., 2003. Asian financial crisis of 1997-1998: a tale of two countries. *Global Business and Finance Review* 8, 61-70

Park, R. K., and Kim, J. H. 2002. An efficiency analysis of Korean banks: a comparative analysis of DEA, FDH, and Malmquist index approach (in Korean), *Kukje Kyungje Yongu* 8, 177-201.

Park, S. R., and Yi, I.S. 2002. The technical efficiency and merger effects in Korean commercial banks (in Korean). *Korean Journal of Money and Finance* 7, 31-60.

Rogers, K. E. 1998. Nontraditional activities and the efficiency of US commercial banks, *Journal of Banking and Finance*, 22, 467-482.

Saunders, A., 2000. *Financial Institutions Management: A Modern Perspective*, McGraw Hill, Third edition.

Shephard, R., 1974. *Theory of Cost and Production Function*, Princeton, Princeton University Press.

Tulkens, H. and Vanden Eeckaut, P., 1995. Non-parametric efficiency, progress and regress measures for panel data: Methodological aspects. *European Journal of Operational Research* 80, 474-499.

Sturm, J-E., and Williams, B., 2004. Foreign bank entry, deregulation and bank efficiency: lessons from the Australian experience. J*ournal of Banking and Finance* 28, 1775-1799.

Weber, W., Domazlicky, B., 2001. Productivity growth and pollution in state manufacturing. *Review of Economics and Statistics* 195-199.

Table 1. Descriptive Statistics

Variable	Mean[1]	Std. Dev.	Minimum	Maximum
Commercial Loans (y_1)	43472	48636	377	359634
Personal Loans (y_2)	18882	41673	294	354823
Securities (y_3)	34939	44350	1437	293702
Demand deposits (y_4)	13038	14955	775	114228
Total loans less non-performing loans ($y_5=y_1+y_2-b_1$)	55305	82654	658	692390
Deposits (y_6)	119851	151228	4241	1151634
Interest income (y_7)	11745	13273	211	91752
Non-interest income (y_8)	5171	7576	1	49939
Fee income (y_9)	946	1182	0	8139
Non-performing loans(b_1)[2]	7049	9019	12	54888
Labor	4094	3568	254	19194
Physical capital (x_2)	6457	6344	329	35381
Deposits (x_3)	119851	151228	4241	1151634
Interest expense (x_4)	8589	9455	36	55740
Non-interest expense (x_5)	8848	12380	175	78791
equity (eq)	9145	10461	431	88385

Notes:

1. The year and number of included banks are: 1992-24, 1993-24, 1994-24, 1995-25, 1996-25, 1997-26, 1998-18, 1999-17, 2000-17, 2001-15, 2002-14 for a total of 229 observations. Labor equals the number of workers, and all other variables are measured in 100 million Korean won.
2. Two newly formed banks in 1999 and four newly formed banks in 2001 reported zero amounts of non-performing loans in their first year of operation and were not included in that year, but were included in subsequent years.

Table 2. Number of National Banks (N) and Regional Banks (R) on the Frontier.

Frontier banks have $\vec{D}_T(x, y, b; g_x, g_y, g_b) = 0$

Year	Total =N+R	Model 1	Model 2	Model 3	Model 4	Model 5
1992	24=14+10	19=10+9	19=10+9	22=12+10	9=7+2	8=4+4
1993	24=14+10	17=9+8	18=9+9	17=9+8	7=6+1	4=1+3
1994	24=14+10	15=8+7	18=10+8	19=10+9	9=6+3	4=2+2
1995	25=15+10	11=6+5	12=7+5	15=9+6	8=6+2	3=3+0
1996	25=15+10	10=7+3	10=7+3	14=9+5	7=5+2	4=2+2
1997	26=16+10	12=6+6	14=7+7	15=8+7	5=4+1	10=8+2
1998	18=12+6	7=7+0	9=9+0	11=9+2	6=6+0	8=7+1
1999	17=11+6	14=11+3	13=10+3	15=10+5	7=6+1	4=3+1
2000	17=11+6	12=8+4	13=0+4	15=11+4	6=5+1	5=4+1
2001	15=9+6	10=5+5	11=6+5	13=8+5	3=3+0	3=2+1
2002	14=8+6	8=4+4	9=5+4	11=7+4	3=3+0	5=2+3

Each model takes $g = (\bar{x}, \bar{y}, \bar{b})$ and includes the equity capital constraint

Outputs-y_1=Commercial loans, y_2=personal loans, y_3=securities investments, y_4=demand deposits, y_5=total loans less non-performing loans (y_1+y_2-b_1), y_6=total deposits, y_7=interest income, y_8=non-interest income, y_9=fee income, b_1=non-performing loans.

Inputs-x_1=full-time workers, x_2=physical capital, x_3=total deposits, x_4=interest expense, x_5=non-interest expense.

Model 1. outputs=(y_1,y_2,y_3,b_1), inputs=(x_1,x_2,x_3)
Model 2- outputs=(y_1,y_2,y_3,y_9,b_1) , inputs=(x_1,x_2,x_3)
Model 3. outputs=(y_1,y_2,y_3,y_4,y_9,b_1), inputs=(x_1,x_2,x_3)
Model 4. outputs=(y_3,y_5,y_6,y_9), inputs=(x_1,x_2)
Model 5. outputs=(y_7,y_8), inputs=(x_4,x_5)

Table 3A. Industry Efficiency: $\sum_{k=1}^{K} \vec{D}_T^k (x^k, y^k, b^k; g_x, g_y, g_b)$

Year	K	Model 1	Model 2	Model 3	Model 4	Model 5
1992	24	0.0434	0.0392	0.0040	0.5925	0.1602
1993	24	0.0904	0.0751	0.0687	0.6220	0.4123
1994	24	0.2572	0.0699	0.0572	0.5415	0.4801
1995	25	0.4418	0.2183	0.1418	0.6261	0.5516
1996	25	0.6258	0.6299	0.4624	1.0119	0.4739
1997	26	1.1390	0.5718	0.5212	1.3741	0.6119
1998	18	1.3474	0.8651	0.5282	1.9150	1.0198
1999	17	0.2418	0.0493	0.0302	1.5667	0.8156
2000	17	0.4615	0.3071	0.0237	1.9359	0.6966
2001	15	0.8006	0.4749	0.1594	3.0931	0.4300
2002	14	1.5389	0.8228	0.1083	1.9379	0.3232

Each model takes $g = (\bar{x}, \bar{y}, \bar{b})$ and includes the equity capital constraint
Outputs-y_1=Commercial loans, y_2=personal loans, y_3=securities investments, y_4=demand deposits, y_5=total loans less non-performing loans($y_1+y_2-b_1$), y_6=total deposits, y_7=interest income, y_8=non-interest income, y_9=fee income, b_1=non-performing loans.

Inputs-x_1=full-time workers, x_2=physical capital, x_3=total deposits, x_4=interest expense, x_5=non-interest expense.

Model 1. outputs=(y_1,y_2,y_3,b_1), inputs=(x_1,x_2,x_3)
Model 2. outputs=(y_1,y_2,y_3,y_9,b_1) , inputs=(x_1,x_2,x_3)
Model 3. outputs=(y_1,y_2,y_3,y_4,y_9,b_1), inputs=(x_1,x_2,x_3)
Model 4. outputs=(y_3,y_5,y_6,y_9), inputs=(x_1,x_2)
Model 5. outputs=(y_7,y_8), inputs=(x_4,x_5)

Table 3B. Industry Inefficiency: $\sum_{k=1}^{K} \vec{D}_T^{k}(x^k, y^k, b^k; g_x, g_y, g_b)$, $g = (g_x, g_y, g_b) = (0, \bar{y}, \bar{b})$

Year	Model 1	Model 2	Model 3	Model 4	Model 5
1992	0.0891	0.0396	0.0052	0.8306	0.3727
1993	0.1394	0.108	0.0826	0.8992	0.8561
1994	0.4316	0.1021	0.0932	0.8174	0.9559
1995	0.7325	0.5341	0.3844	0.9517	1.1823
1996	1.4552	1.0297	0.8417	1.7884	1.0527
1997	2.4211	0.8545	0.7819	2.5529	1.1587
1998	3.1274	1.6748	1.086	4.3569	1.9213
1999	0.3026	0.1011	0.0674	3.6032	1.6126
2000	1.1877	0.6133	0.0403	4.3043	1.3579
2001	1.8247	0.9569	0.2111	8.3811	0.8869
2002	2.8233	1.8255	0.1632	5.6594	0.7029

Each model takes $g = (g_x, g_y, g_b) = (0, \bar{y}, \bar{b})$ and includes the equity capital constraint

Outputs-y_1=Commercial loans, y_2=personal loans, y_3=securities investments, y_4=demand deposits, y_5=total loans less non-performing loans($y_1+y_2-b_1$), y_6=total deposits, y_7=interest income, y_8=non-interest income, y_9=fee income, b_1=non-performing loans.

Inputs-x_1=full-time workers, x_2=physical capital, x_3=total deposits, x_4=interest expense, x_5=non-interest expense.

Model 1. outputs=(y_1,y_2,y_3,b_1), inputs=(x_1,x_2,x_3)
Model 2. outputs=(y_1,y_2,y_3,y_9,b_1) , inputs=(x_1,x_2,x_3)
Model 3. outputs=(y_1,y_2,y_3,y_4,y_9,b_1), inputs=(x_1,x_2,x_3)
Model 4. outputs=(y_3,y_5,y_6,y_9), inputs=(x_1,x_2)
Model 5. outputs=(y_7,y_8), inputs=(x_4,x_5)

Table 3C. Industry Inefficiency: $\sum_{k=1}^{K} \vec{D}_T^{k}(x^k, y^k, b^k; g_x, g_y, g_b) \quad g = (g_x, g_y, g_b) = (\bar{x}, 0, 0)$

	Model 1	Model 2	Model 3	Model 4	Model 5
1992	0.2348	0.1763	0.0128	1.5211	0.2746
1993	0.2213	0.2028	0.1762	1.5407	0.7740
1994	0.2026	0.1778	0.1431	1.3449	0.9202
1995	0.8964	0.7150	0.4489	1.6416	1.0218
1996	1.5679	1.3351	1.0253	2.3691	0.8628
1997	3.1394	2.3307	2.2946	3.7336	1.2906
1998	2.2276	1.3689	0.8300	3.5357	2.1564
1999	0.1046	0.1046	0.0624	2.3463	1.6428
2000	0.6154	0.4607	0.0508	3.5024	1.4302
2001	1.5494	0.6010	0.3553	4.7789	0.8362
2002	1.7658	1.1716	0.2182	2.8291	0.5937

Outputs-y_1=Commercial loans, y_2=personal loans, y_3=securities investments, y_4=demand deposits, y_5=total loans less non-performing loans($y_1+y_2-b_1$), y_6=total deposits, y_7=interest income, y_8=non-interest income, y_9=fee income, b_1=non-performing loans.

Inputs-x_1=full-time workers, x_2=physical capital, x_3=total deposits, x_4=interest expense, x_5=non-interest expense.

Model 1. outputs=(y_1,y_2,y_3,b_1), inputs=(x_1,x_2,x_3)
Model 2. outputs=(y_1,y_2,y_3,y_9,b_1) , inputs=(x_1,x_2,x_3)
Model 3. outputs=(y_1,y_2,y_3,y_4,y_9,b_1), inputs=(x_1,x_2,x_3)
Model 4. outputs=(y_3,y_5,y_6,y_9), inputs=(x_1,x_2)
Model 5. outputs=(y_7,y_8), inputs=(x_4,x_5)

Table 4A. Decomposition of the Industry Productivity Indicator
L=productivity indicator, EFFCH =efficiency change indicator,
TECH=technical change indicator

Years		Model 1	Model 2	Model 3	Model 4	Model 5
1992-93	L=	0.4664	0.4180	0.2209	0.3871	-0.2211
	EFFCH+	-0.0470	-0.0359	-0.0647	-0.0295	-0.2521
	TECH	0.5134	0.4539	0.2856	0.4166	0.0311
1993-94	L=	0.9700	0.7476	0.6795	1.2165	-0.0369
	EFFCH+	-0.1668	0.0052	0.0115	0.0805	-0.0678
	TECH	1.1368	0.7424	0.6680	1.1360	0.0310
1994-95	L=	0.3521	0.1519	0.1460	0.4082	-0.0051
	EFFCH+	-0.1846	-0.1484	-0.0846	-0.0846	-0.0715
	TECH	0.5367	0.3003	0.2306	0.4928	0.0665
1995-96	L=	1.1203	1.0559	0.1248	1.1530	0.0945
	EFFCH+	-0.1840	-0.4116	-0.3206	-0.3858	0.0777
	TECH	1.3043	1.4675	0.4454	1.5388	0.0168
1996-97	L=	4.1105	0.9604	2.8313	2.3146	5.1052
	EFFCH+	-0.2878	0.1068	-0.0101	-0.1334	-0.1380
	TECH	4.3983	0.8536	2.8414	2.4480	5.2432
1997-98	L=	2.9569	0.4788	1.0403	3.6172	3.1475
	EFFCH+	-0.3173	-0.4257	-0.1315	-0.8891	-0.4885
	TECH	3.2742	0.9045	1.1718	4.5063	3.6360
1998-99	L=	2.3757	1.1465	0.7974	1.1287	0.3250
	EFFCH+	0.5974	0.3484	0.2783	-0.1688	-0.2382
	TECH	1.7783	0.7981	0.5191	1.2975	0.5632
1999-00	L=	2.0175	-0.1141	0.2469	1.7581	0.2337
	EFFCH+	-0.2197	-0.2578	0.0065	-0.3692	0.1190
	TECH	2.2372	0.1437	0.2404	2.1273	0.1147
2000-01	L=	2.5791	0.1993	0.4722	-0.0789	0.4749
	EFFCH+	-0.3391	-0.1678	-0.1357	-1.2242	0.2666
	TECH	2.9182	0.3671	0.6079	1.1453	0.2083
2001-02	L=	2.5392	1.1761	0.8790	1.5212	0.4057
	EFFCH+	-0.7383	-0.3479	0.0511	0.9320	0.0850
	TECH	3.2775	1.5240	0.8279	0.5892	0.3207

Each model takes $g = (\bar{x}, \bar{y}, \bar{b})$ and includes the equity capital constraint

Outputs-y_1=Commercial loans, y_2=personal loans, y_3=securities investments, y_4=demand deposits, y_5=total loans less non-performing loans(y_1+y_2-b_1), y_6=total deposits, y_7=interest income, y_8=non-interest income, y_9=fee income, b_1=non-performing loans.
Inputs-x_1=full-time workers, x_2=physical capital, x_3=total deposits, x_4=interest expense, x_5=non-interest expense.

Model 1. outputs=(y_1,y_2,y_3,b_1), inputs=(x_1,x_2,x_3)
Model 2. outputs=(y_1,y_2,y_3,y_9,b_1) , inputs=(x_1,x_2,x_3)
Model 3. outputs=(y_1,y_2,y_3,y_4,y_9,b_1), inputs=(x_1,x_2,x_3)
Model 4. outputs=(y_3,y_5,y_6,y_9), inputs=(x_1,x_2)
Model 5. outputs=(y_7,y_8), inputs=(x_4,x_5)

Table 4B. Industry Productivity Change for $g = (g_x, g_y, g_b) = (0, \bar{y}, \bar{b})$

Year		Model 1	Model 2	Model 3	Model 4	Model 5
1992-93	L	0.6466	0.5712	0.5426	0.5168	-0.4098
	EFFCH	-0.0503	-0.0684	-0.0774	-0.0686	-0.4834
	TECH	0.6969	0.6396	0.6200	0.5854	0.0736
1993-94	L	1.3639	2.1921	2.2612	1.5248	-0.0297
	EFFCH	-0.2922	0.0059	-0.0106	0.0818	-0.0998
	TECH	1.6561	2.1862	2.2718	1.4430	0.0701
1994-95	L	0.4496	0.2393	0.4632	0.6118	-0.0227
	EFFCH	-0.3009	-0.4320	-0.2912	-0.1343	-0.2264
	TECH	0.7505	0.6713	0.7544	0.7461	0.2037
1995-96	L	3.3867	3.5049	2.9440	1.6608	0.1554
	EFFCH	-0.7227	-0.4956	-0.4573	-0.8367	0.1296
	TECH	4.1094	4.0005	3.4013	2.4975	0.0258
1996-97	L	16.4065	5.3650	4.0474	2.9413	5.4460
	EFFCH	-0.7405	0.2239	0.1085	-0.3613	-0.1060
	TECH	17.1470	5.1411	3.9389	3.3026	5.5520
1997-98	L	9.6528	18.7525	4.5991	5.2917	3.2049
	EFFCH	-0.9687	-1.0562	-0.5242	-2.3662	-0.9136
	TECH	10.6215	19.8087	5.1233	7.6579	4.1185
1998-99	L	5.1561	12.5206	-5.7888	2.1883	0.8398
	EFFCH	1.5999	0.6123	0.4907	-0.6584	-0.5172
	TECH	3.5562	11.9083	-6.2795	2.8467	1.3570
1999-00	L	4.7283	4.7165	1.2257	4.0935	0.4910
	EFFCH	-0.8851	-0.5122	0.0271	-0.7011	0.2547
	TECH	5.6134	5.2287	1.1986	4.7946	0.2363
2000-01	L	8.9562	9.6685	8.9480	-1.1332	0.9136
	EFFCH	-0.6370	-0.3436	-0.1708	-4.3243	0.4710
	TECH	9.5932	10.0121	9.1188	3.1912	0.4426
2001-02	L	7.5942	8.6655	11.4210	3.7210	0.8227
	EFFCH	-0.9986	-0.8686	0.0479	2.2801	0.1420
	TECH	8.5928	9.5341	11.3731	1.4409	0.6807

Table 4C. Industry Productivity Change for $g = (g_x, g_y, g_b) = (\bar{x}, 0, 0)$

Year		Model 1	Model 2	Model 3	Model 4	Model 5
1992-93	L	2.6752	3.7200	2.0899	1.0056	-0.4442
	EFFCH	0.0135	-0.0265	-0.1634	-0.0196	-0.4994
	TECH	2.6617	3.7465	2.2533	1.0252	0.0553
1993-94	L	3.5494	7.6438	5.1135	4.8474	-0.0923
	EFFCH	0.0187	0.0250	0.0331	0.1958	-0.1462
	TECH	3.5307	7.6188	5.0804	4.6516	0.0539
1994-95	L	0.2159	0.9714	0.6973	2.1374	-0.0265
	EFFCH	-0.6938	-0.5372	-0.3058	-0.2967	-0.1016
	TECH	0.9097	1.5086	1.0031	2.4341	0.0751
1995-96	L	4.8750	5.1777	5.0680	4.2729	0.0941
	EFFCH	-0.6715	-0.6201	-0.5764	-0.7275	0.1590
	TECH	5.5465	5.7978	5.6444	5.0004	-0.0650
1996-97	L	4.5503	108.5506	30.5942	8.7087	0.3993
	EFFCH	-0.4336	-0.0160	-0.2897	-0.8357	-0.4278
	TECH	4.9839	108.5666	30.8839	9.5444	0.8271
1997-98	L	4.2523	15.3593	78.4064	6.7250	0.0631
	EFFCH	0.6660	0.7217	1.2326	-0.7121	-1.0396
	TECH	3.5863	14.6376	77.1738	7.4371	1.1027
1998-99	L	3.9700	4.2045	4.0237	2.4334	0.6541
	EFFCH	1.3375	0.5955	0.4051	0.2787	-0.4242
	TECH	2.6325	3.6090	3.6186	2.1547	1.0783
1999-00	L	6.4828	14.1977	15.5191	2.8887	0.4421
	EFFCH	-0.5108	-0.3561	0.0116	-1.1561	0.2126
	TECH	6.9936	14.5538	15.5075	4.0448	0.2295
2000-01	L	12.5498	-64.4835	1.5342	0.4178	0.9888
	EFFCH	-0.9340	-0.1403	-0.3045	-1.4175	0.5940
	TECH	13.4838	-64.3432	1.8387	1.8353	0.3948
2001-02	L	6.0849	10.0952	12.6398	2.6725	0.7994
	EFFCH	-0.2164	-0.5706	0.1371	1.5571	0.1972
	TECH	6.3013	10.6658	12.5027	1.1154	0.6022

Table 5-Number of frontier banks from previous periods that would be efficient for the 2002 technology and tests for technical change

Previous period	Model 1	Model 2	Model 3	Model 4	Model 5
1992	8	13	21	1	6
1993	2	6	7	0	1
1994	1	6	7	0	2
1995	2	3	4	0	1
1996	2	2	5	0	1
1997	6	9	10	1	1
1998	6	9	9	6	5
1999	6	10	12	3	2
2000	8	11	12	5	3
2001	10	11	12	3	3
2002	8	9	11	3	5
Is $f(\vec{D}_T^{2002}(x^{1992}, y^{1992}, b^{1992}; \bar{x}, \bar{y}, \bar{b}) = g(\vec{D}_T^{2002}(x^{1992}, y^{1992}, b^{1992}; \bar{x}, \bar{y}, \bar{b})$					
T-value[1]	8.32	5.90	0.15	24.31	0.32
Is $f(\vec{D}_T^{1992}(x^{2002}, y^{2002}, b^{2002}; \bar{x}, \bar{y}, \bar{b}) = g(\vec{D}_T^{2002}(x^{2002}, y^{2002}, b^{2002}; \bar{x}, \bar{y}, \bar{b})$					
T-value[1]	4,59	3.88	1.64	4.48	2.46

1. Based on Qi Li's (1996) T-test. Critical T=1.71, α=.05

Each model takes $g = (\bar{x}, \bar{y}, \bar{b})$ and includes the equity capital constraint

Outputs-y_1=Commercial loans, y_2=personal loans, y_3=securities investments, y_4=demand deposits, y_5=total loans less non-performing loans (y_1+y_2-b_1), y_6=total deposits, y_7=interest income, y_8=non-interest income, y_9=fee income, b_1=non-performing loans.

Inputs-x_1=full-time workers, x_2=physical capital, x_3=total deposits, x_4=interest expense, x_5=non-interest expense.

Model 1. outputs=(y_1,y_2,y_3,b_1), inputs=(x_1,x_2,x_3)
Model 2. outputs=(y_1,y_2,y_3,y_9,b_1) , inputs=(x_1,x_2,x_3)
Model 3. outputs=(y_1,y_2,y_3,y_4,y_9,b_1), inputs=(x_1,x_2,x_3)
Model 4. outputs=(y_3,y_5,y_6,y_9), inputs=(x_1,x_2)
Model 5. outputs=(y_7,y_8), inputs=(x_4,x_5)

Figure 1. The Directional Technology Distance Function

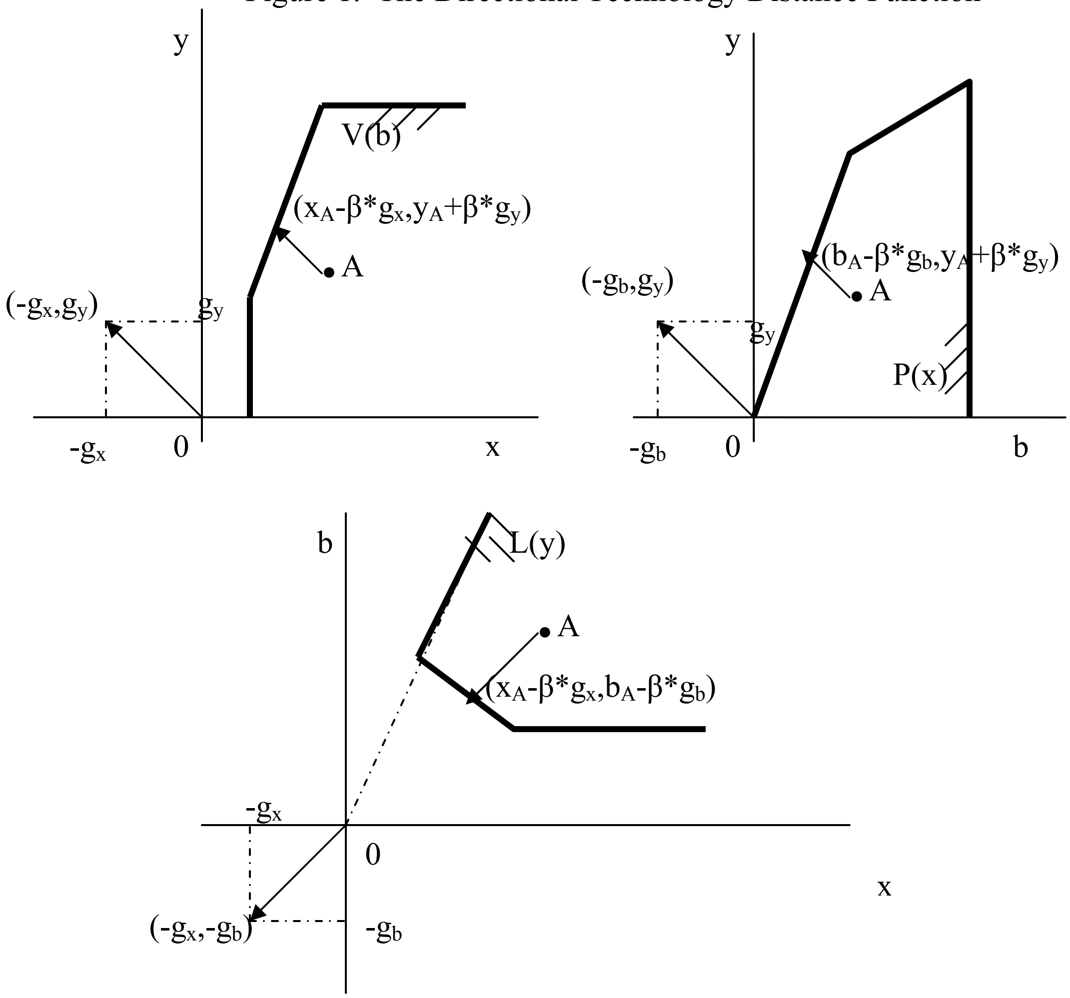

Figure 2-Industry Inefficiency

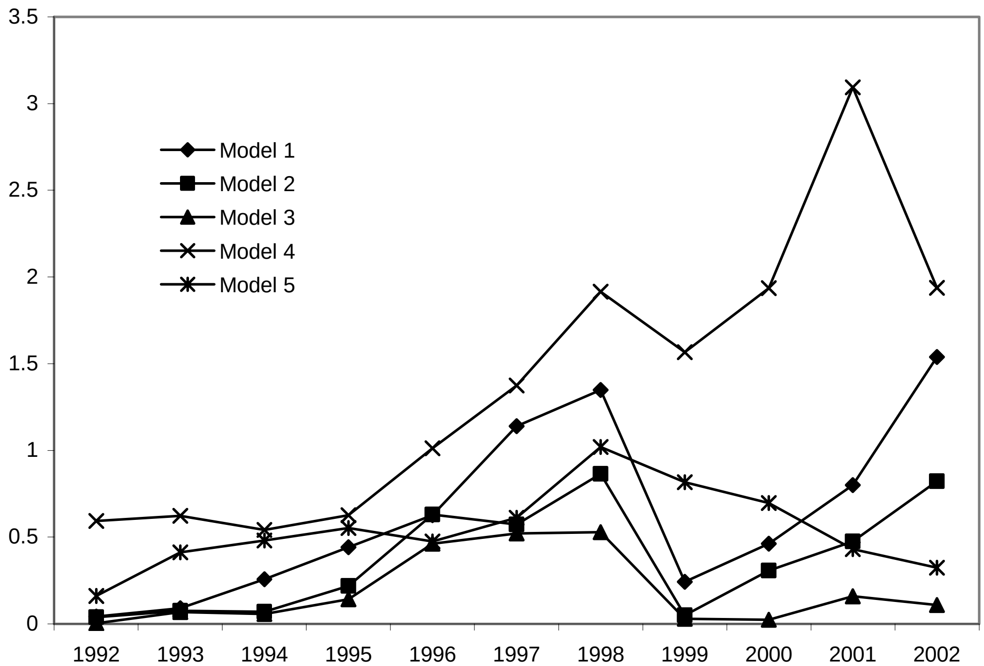

Figure 3-Industry Efficiency Change

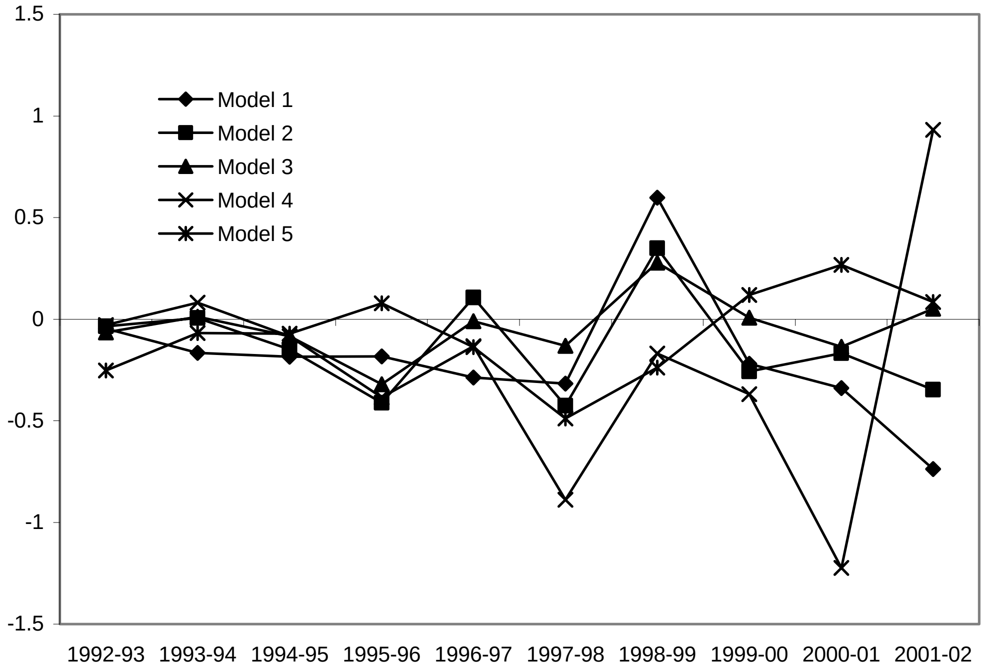

Figure 4-Industry Technical Change

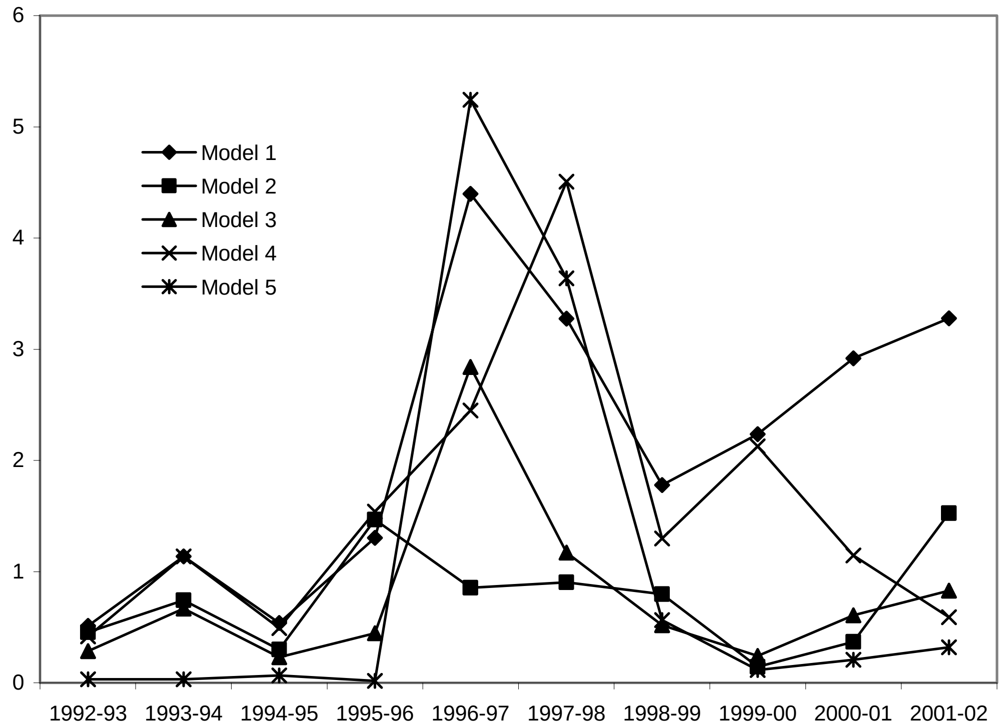

Figure 5-Industry Productivity Change